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Effect of a mixture of canola-chia oils and gelatin addition on a pound cake reduced in margarine

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Abstract

This work evaluated the effect of the addition of a mixture of canola-chia oils (4:1) and 1% of gelatin on batter (specific gravity and rheology) and quality properties (volume, color, firmness, fatty acid profile, and sensory attributes) of a pound cake reduced in margarine (70% and 90%). Specific gravity (SG) significantly ($p < .05$) increased as the content of the mixture of oils increased and when the gelatin was added. Besides, the storage (G') and loss (G'') modulus decreased as the percentage of mixture of oils increased, and these values increased with the addition of gelatin. The reduction of 70% of margarine did not modify apparently the gelatinization temperature and protein coagulation during baking. Sensorially, the reduction of cake at 70% and with 1% of gelatin (70-1) was the most accepted, and it also showed a better balance of omega-6 and omega-3 (linoleic and linolenic; 1.4:1).

Practical applications

This study allows us to evaluate the effect of a mixture of canola-chia oils and gelatin addition on the quality and processing of a pound cake reduced in margarine (70% and 90%). Cake producers can reduce or substitute the margarine in a pound cake formula without changing the final cake quality. The study demonstrated that the use of the mixture of these vegetable oils noticeably improves the balance of omega-6 and omega-3, in this way its consumption becomes a healthier alternative. It is necessary to notice that the use of gelatin enhances the sensory properties of the pound cake. Therefore, the mixture of canola-chia oils and gelatin improves the nutritional and sensory quality of the pound cake reduced in margarine.

1 | INTRODUCTION

The main ingredients in a traditional pound cake formula are flour, fat, sugar, and egg, which are normally added in the same proportions. The behavior of each ingredient during the process contributes to the final cake quality. Fat is an important and functional ingredient on cake elaboration, as it can retain air, and improves taste quality (Román, Santos, Martínez, & Gómez, 2015). In addition, fat forms a complex between the lipid and other compounds during baking, which delays the gelatinization process since it retards the water transport into the starch granules (Felisberto et al., 2015). Thus, a change on the concentration or type of fat affects the texture, volume, and other quality characteristics of the pound cake (Felisberto et al., 2015).

Commonly, margarine is the fat used in the pound cake elaboration. This is a hydrogenated shortening that is characterized by a high level of trans fats content (Doan, Tavernier, Okuro, & Dewettinck, 2018). In order to reduce it, the use of saturated fats have been increased; however, consumers look for healthier foods, but if the saturated fraction of lipids is substituted by an unsaturated fat, such as vegetable oils, although these provide essential fatty acids, the expected quality is not obtained (Doan et al., 2018). Therefore, researchers make efforts for evaluating different alternatives to replace them (Patel & Dewettinck, 2015) without a change in the product quality.

Few gums, protein hydrolysates, and modified starches are employed in baking (Saha & Bhattacharya, 2010); the addition of gums and emulsifiers considerably improves the quality of a hydrogenated fat-reduced pound cake with vegetable oil, as well as it improves the balance of unsaturated fatty acids (Kumari, Jeyarani, Sowmya, & Indrani, 2011). Other fat substitutes as carbohydrate based (gums, fiber, and modified starches; Eduardo, Svanberg, & Ahrné, 2014; Quiles et al., 2018), lipid based (emulsifiers and oils; Kumari et al., 2011), protein based (concentrates and microparticulates), and their combinations (Matos, Sanz, & Rosell, 2014; Psimouli & Oreopoulou, 2013; Jarpa-Parra et al., 2017) have been studied. Gelatin is a protein hydrocolloid which has functional properties such as moisture retention and gel formation (Badui, 2013; Sánchez-Paz et al., 2018), however, the evaluation of the effect of its addition on baked goods has not been widely studied; therefore more studies about it could provide information to consider it as an alternative in the baking process.

Western diet is characterized by a high intake of omega-6 linoleic acid and a low consumption of omega-3 linolenic acid. In this way, the omega-6:omega-3 ratio is far from the FAO/OMS recommendation (2012), which should be 2:1 (linoleic acid—α-linolenic acid). These polyunsaturated fatty acids have a structural role in cell membrane phospholipids and they are substrates for the synthesis of different mediators which model multiple processes such as immunity, infectious, and inflammatory illnesses (Holman, 1998). Chia seed offers the highest known percentage of α-linolenic acid (omega-3), between 50% and 64% (Jiménez, Masson, & Quitral, 2013), so partial substitution of wheat flour by chia flour have been carried out (15%), achieving an acceptable omega-6–omega-3 content (Luna, Lopes, Sammána, & Kil Chang, 2013). Besides, chia oil increases approximately threefold the content of omega-3 compared with its flour content (Ayerza & Coates, 2011). It is considered a better choice to include it into baking goods. Another useful vegetable oil is canola oil, which has a significant proportion of oleic and linoleic acid that imparts oxidation stability; furthermore, it has the lowest concentration of saturated fatty acids (6%), the highest concentration of monounsaturated (61%), and the lowest omega-6/omega-3 ratio (Giacopini de Zambrano 2012).

Hence, the aim of this work was to evaluate the effect of the addition of a mixture of canola-chia oils and gelatin on the quality of a pound cake, reduced at 70% and 90% in margarine, measuring viscoelastic properties of the batter and quality characteristics of the cake such as volume, color, firmness, springiness, fatty acid profile, and sensory acceptance.

2 | MATERIALS AND METHODS

2.1 | Materials

Wheat flour with a protein content of 10.88% (reported by the supplier) was purchased from San Antonio, Tres Estrellas, Mexico; 260°B gelatin was purchased from Gelita, Mexico; baking powder was purchased from Royal, Kraft Foods of Mexico; margarine was purchased from Iberia, Unilever Mexico; canola oil was purchased Canoil, AGYDSA, Mexico; and chia-seed oil pressed in cold and purified water was purchased from Bonafont, Mexico. The rest of the ingredients (whole egg and sugar) were purchased from local suppliers.

2.2 | Cake elaboration

Pound cakes were prepared according to Table 1, based on the method of Sánchez-Paz et al. (2018) as follows: (a) margarine, sugar, and canola-chia oil were mixed (63,232, Hamilton Beach Brands, Inc., Southern Pines, NC, USA) for 2 min at low speed (306 rpm), 2 min at medium speed (380 rpm), and 1 min at high speed (450 rpm); (b) whole egg was added to the fat mixture and it was mixed for 2 min at low speed and 2 min at medium speed; (c) wheat flour and sifted baking powder were mixed for 1 min at low speed and, (d) gelatin was dissolved in cold water and after it was heated, then gelatin was added to the mixture and it was mixed for 2 min at low speed. The batter (600 g) was placed in an aluminum pound cake mold (21 × 11 × 6 cm) and baked at 180°C for 35 min in a preheated oven (Rational Self-Cooking Center whitefficiency, Germany).

2.3 | Batter properties

Specific gravity (SG) was calculated by the ratio of the weight of a standard volume of the batter and the weight of an equal volume of water at 20°C (Method 72-10-AACC, 2010). The viscoelastic behavior of the batters during baking were evaluated by the storage modulus (G') and loss modulus (G'') values at constant frequency (1.0 Hz) and amplitude (1%), using a rheometer (HAAKE MARS III, Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA) with a parallel plate–plate of 60 mm and a constant gap height of 1.0 mm, from 20 to 120°C. The heating rate of the sample was 5°C/min. To

TABLE 1 Pound cake formulations with different levels of margarine, mixture of canola-chia oils (4:1) and gelatin

		Margarine reduction (%)		Gelatin added (%)	
		70	90	1.0	1.0
Formulation (g) code	Control	70-0	90-0	70-1	90-1
Wheat flour	250	250	250	250	250
Baking powder	2	2	2	2	2
Sugar	150	150	150	150	150
Margarine	150	45	15	45	15
Whole egg	136	136	136	136	136
Water	56	56	56	56	56
Canola oil	–	60	80	60	80
Chia oil	–	15	25	15	25
Gelatin	–	0	0	2.5	2.5

minimize the slip of the samples during the experiments, serrated parallel plates were utilized (Román et al., 2015).

2.4 | Pound cake quality

The volume was determined by the seed displacement method (10-05, AACC, 2010). The color of the cakes was measured using a Minolta Chromameter (CR_300, Minolta Corporation, Ramsey, NJ); the analysis was based on the $L^*a^*b^*$ or CIE $L^*a^*b^*$ system defined by the CIE (International Commission on Illumination) in 1976. The pound cake crumb firmness and springiness were measured 24 hr after baking using a TA.XT Plus (Stable Micro Systems, Surrey, UK). Pieces of pound cakes (25 mm of thickness) were compressed twice until 40% of the original height using a cylindrical probe of 50 mm of diameter. The texture analysis was done at speed of 1.0 mm/s for the pretest, 1.7 mm/s for the test, and 10.0 mm/s for the posttest, according to the 74-09.01, AACC (2010) method.

2.5 | Sensory analysis

A ranking discrimination test was carried out with 58 untrained judges, 28 men and 30 women between 15 and 65 years of age, to compare the acceptability of the studied samples (Stone, Bleibaum, & Thomas, 2012). An analysis of variance was done utilizing the Statgraphics X64 program to interpret the results.

2.6 | Fatty acid profile analysis

The separation of fatty acid methyl esters was done using gas chromatography (GC-MS QP2010, Shimadzu, USA), in order to determine the amount of saturated and unsaturated fatty acids. The samples were prepared according to the 969.33 and 963.22 methods (AOAC, 2005).

2.7 | Data analysis

All experiments were done in triplicate. Data were analyzed using a one-way analysis of variance (ANOVA) and a Tukey's test using the Statgraphics X64.

3 | RESULTS AND DISCUSSION

3.1 | Batter properties

The SG indicates the quantity of air into the batter, and lower values of SG denote higher air content. Also, SG is related to viscosity and final quality of the pound cake. Table 2 shows the effect of the mixture of canola-chia oils and gelatin addition on the SG of pound cake reduced in margarine; the mixture of oils (70-0 and 90-0) significantly ($p < .05$) increased the SG values compared to the cake control value. This result is according to the the finding of Kumari et al. (2011) because the same tendency was observed when vegetable oils are added to cake batters. Furthermore, the addition of gelatin (70-1 and 90-1) significantly ($p < .05$) increased the SG of the oily cakes; gelatin is a highly hydrophilic proteic hydrocolloid that forms a gel when it is dispersed in water because of the presence of a large number of hydroxyl groups (–OH); gel formation decreases the available water molecules, increases the viscosity of the batter, and decreases the incorporation of air (Saha & Bhattacharya, 2010; Sánchez-Paz et al., 2018). Figure 1 shows the behavior of the fats in the cake batters during creaming (margarine–oil–sugar). This mixing stage is important because the retention of air and the formation of air-in-fat emulsion occur. Figure 1a shows that, when the concentration of mixture of canola-chia oils is higher, 90-0, only 10% of margarine, fats did not have enough capacity to incorporate air, probably due to lower viscosity which produced unstable emulsions and coalescence of the air bubbles (Kumari et al., 2011). Figure 1b shows that a higher content of margarine, 70-0, 30% of margarine resulted in a soft and a creamy emulsion because margarine could act as an emulsifying agent between oil and the water favoring the stability of the fat–air–water interphase (Brooker, 1993). Figure 1c shows that when only margarine is used (Control), apparently there is not an incorporation of air; however, a homogeneus mixture is observed.

3.2 | Viscoelastic properties of the cake batters during heating

The viscoelastic changes in the cake batters during baking process (Figures 2 and 3) were measured by the viscosity (G'') and elasticity modulus (G') with constant values of frequency (1 Hz) and amplitude

TABLE 2 Quality characteristics of cake batter and pound cake

	Cake batter	Pound cake		
	Specific gravity (SG)	Volume (cm^3)	Firmness (N)	Springiness
Control	0.96 ± 0.003^a	$1,058 \pm 42.7^a$	82.50 ± 7.80^d	0.708 ± 0.053^a
70-0	0.99 ± 0.01^b	$1,197 \pm 9.7^b$	35.71 ± 3.70^a	0.758 ± 0.020^a
70-1	1.01 ± 0.02^{bc}	$1,010 \pm 73.5^a$	59.51 ± 6.53^c	0.771 ± 0.006^a
90-0	1.03 ± 0.01^c	$1,002 \pm 39.6^a$	49.69 ± 5.82^b	0.779 ± 0.032^a
90-1	1.06 ± 0.01^d	$1,026 \pm 77.3^a$	54.35 ± 9.44^{bc}	0.860 ± 0.097^a

[a]Values followed by different letter in the same column are significantly different ($p < .05$).

(a) 90-0 **(b)** 70-0 **(c)** Control

FIGURE 1 Appearance of the cake batter in the first stage of mixing (creaming). (a) 90-0: 10% of margarine; (b) 70-0: 30% of margarine; (c) control: 100% of margarine

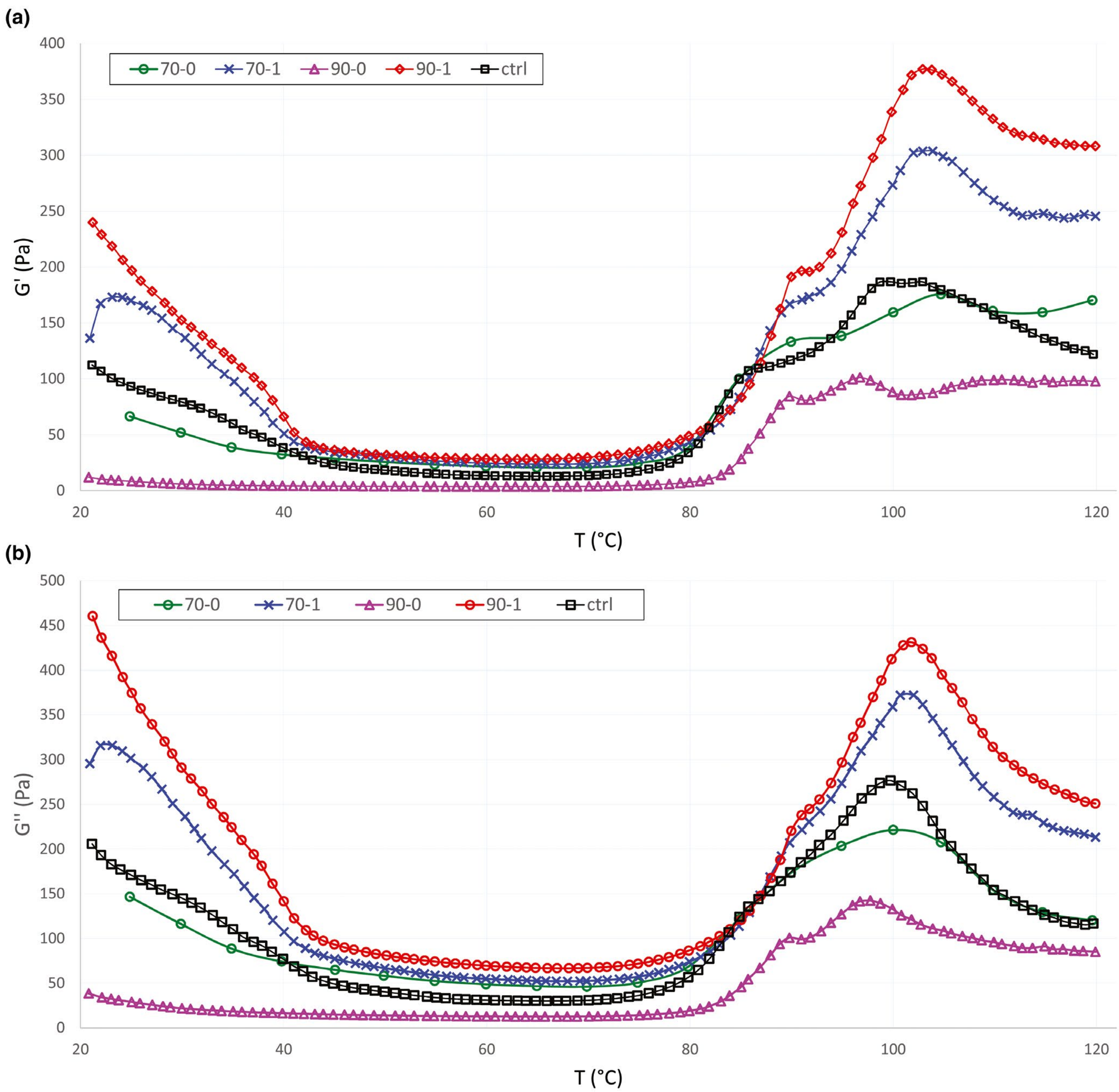

FIGURE 2 Effect of temperature on viscoelastic behavior of different batters reduced in margarine (a) Storage modulus G′ and (b) Loss modulus G″

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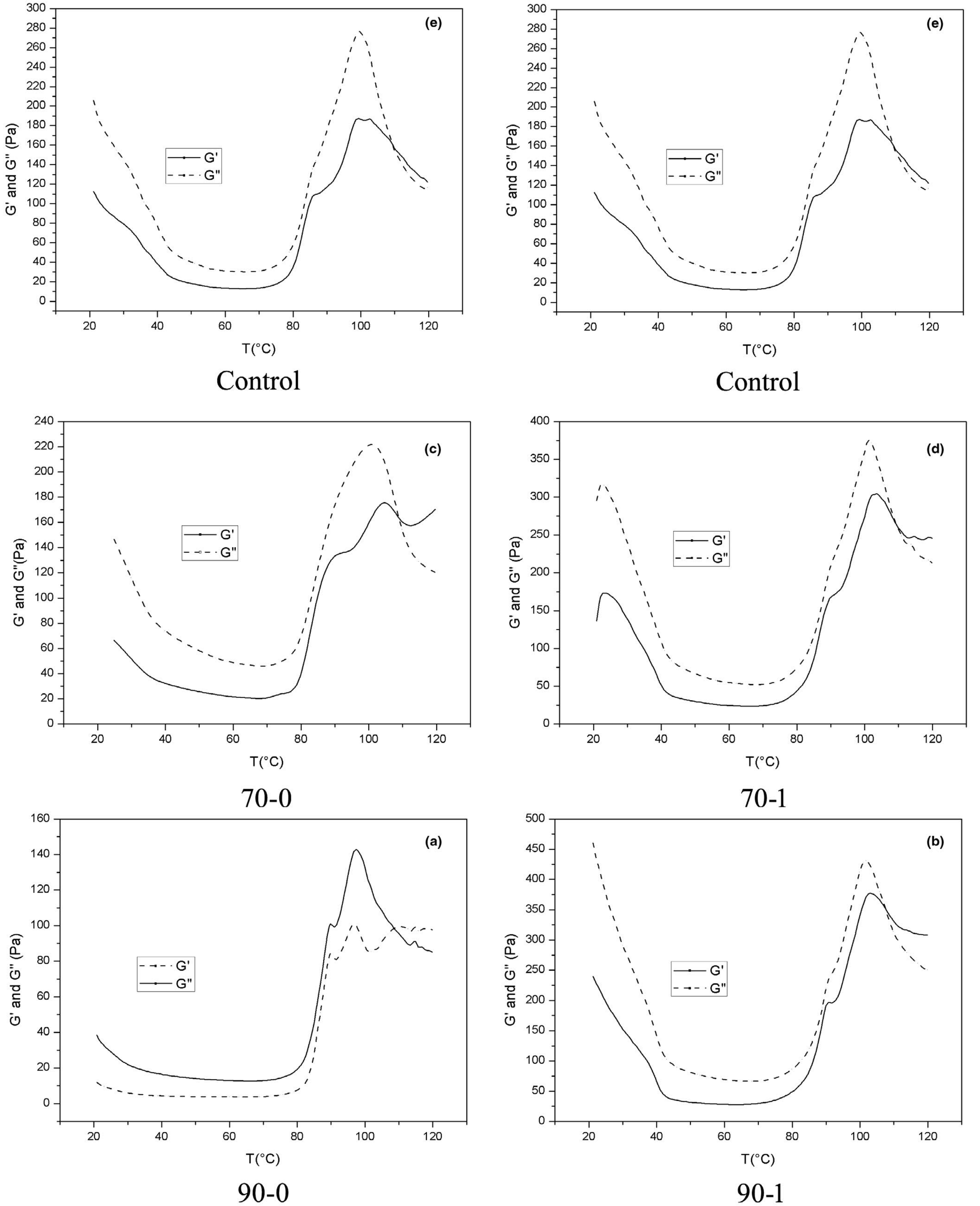

FIGURE 3 Viscoelastic modules G' (storage) and G'' (loss) at different temperatures

(1.0%) on the linear region; Power law model described the rheological behavior of the batters on the temperature range from 20 to 120°C. The addition of the mixture of canola-chia oils in the pound cakes reduced in margarine (90-0 and 70-0) significantly ($p < .05$) decreased the storage (G') and the loss (G'') modulus compared to the control at 20°C (Figure 2). These results are related to their SG values (Table 2), as a lower retention of air in the batter (Figure 1a) leads to a lower storage (G') and loss modulus (G''; Román et al., 2015). In the opposite way, the addition of gelatin in batters (70-1 and 90-1) significantly ($p < .05$) increased the G' and G'' modulus at 20°C compared to the batter cake without gelatin (70-0 and 90-0) and to the control (Figure 2); these results are due to the gelatin gel formation, as gelatin retains water and increases the viscosity. As temperature increases, the viscosity decreases rapidly due to the melting of the solid fat and in the case of the gelatin addition, because of the thermoreversible stability of gelatin gel. The gelatin gel is stabilized through hydrogen bonds between the hydroxyl groups of the protein chain and water; they are weak bonds that break easily, so gelatin gel melts at relatively low temperature, as they can melt in the mouth (Saha & Bhattacharya, 2010). Figure 2 also shows that the 90-0 batter cake had the lowest G' and G'' values (<50 Pa) until approximately 80°C, while the other batters did not descend drastically because of a higher margarine content or gelatin addition.

During the heating from 20 to 100°C (Figure 3), all the cake batters had predominantly a viscous behavior rather than an elastic one. The overlapping of all the curves (G' and G'') at approximately 109°C showed the temperature of the change from a liquid to a solid phase. This result shows that the addition of gelatin or mixture of canola-chia oils did not significantly modify the temperature at which this change occurs. Besides, the rapid increase in viscosity of the batter began at approximately 78°C for the control, 70-0 and 70-1 batters, but in the 90-0 and 90-1 batters began at approximately at 81°C (Figure 3); therefore, it seems that as the minor content of margarine, this temperature raised. The increase in viscosity is related to the gelatinization and protein coagulation; according to Deleu et al. (2019), starch gelatinization and egg protein denaturation depend on the sucrose content in the pound cake formula, and gelatinization temperature ranges from 54 to 86°C, while egg protein denaturation temperature ranges from 63 to 98°C; however, fat delays gelatinization process because it retards the transport of water into the starch granule due to the formation of complexes between lipid and amylose during baking (Felisberto et al., 2015), and it also interferes in the formation of the protein network, shortening, and weakening the structure, thus producing a softer crumb.

3.3 | Pound cake quality

The volume values of the pound cakes of the 70-1, 90-0, and 90-1 cakes (Table 2) were not significantly different ($p < .05$) from the control, while the 70-0 cake had the highest volume value and the best cake appearance (Figure 4). Although the SG values between control and 70-0 were significantly different ($p < .05$), the viscoelastic behavior of 70-0 was the most similar to the control (Figure 2). Besides, the margarine, which is itself a water-in-oil emulsion (W/O), could act as an emulsifying agent between vegetable oils and water during the cake mixing and during the baking process, when the air bubbles begin to expand, the liquid fat could cover the interior part of the bubble, forming an uniform coat, facilitating their expansion without breaking and increasing the final volume (Brooker, 1993). Nevertheless, the lower amount of air incorporated into the control batter (100% margarine; Figure 1c) produced a minor volume value in this formula. Firmness and springiness values are shown in Table 2. The addition of the mixture of vegetable oils significantly ($p < .05$) reduced the firmness compared to the control value. The mixture of solid and liquid fat distributed more uniformly the components of the cake batter (Figure 1b) producing a softer crumb (Figure 4). Control had the highest firmness value probably due to the proportion of saturated fats, which prevents the expansion of the air bubbles during baking, and once the cake cools these fats solidify. The springiness values did not significantly change ($p < .05$) by the addition of vegetable oils and gelatin. The color of the cakes of all formulations (70-0, 70-1, 90-0, and 90-1) were significantly ($p < .05$) different from the control (Table 3), as their luminosity (L) was significantly ($p < .05$) lower than the control. According to Akesowan

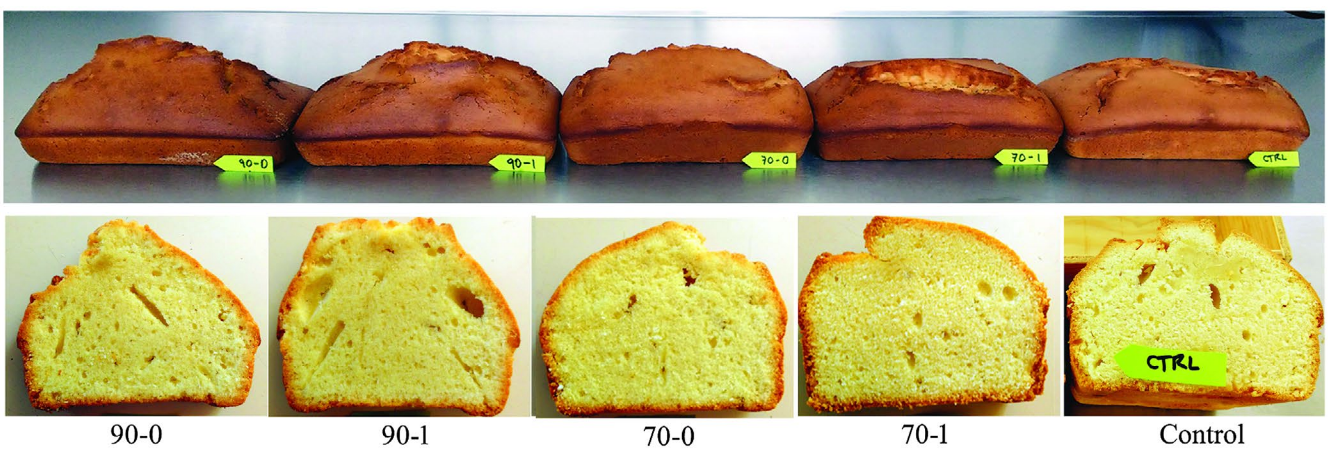

FIGURE 4 Appearance and crumb structure of pound cakes

Journal of Food Processing and Preservation

TABLE 3 Color of pound cake crumbs

	Control	70-0	70-1	90-0	90-1
L	66.5 ± 2.5[b]	60.0 ± 1.2[a]	59.1 ± 1.9[a]	58.4 ± 2.4[a]	56.6 ± 2.4[a]
a	11.7 ± 1.1[a]	11.0 ± 1.3[a]	12.1 ± 0.4[b]	11.2 ± 0.9[a]	10.6 ± 1.3[a]
b	20.5 ± 1.4[b]	18.7 ± 0.6[a]	20.6 ± 1.3[b]	16.4 ± 2.5[a]	16.1 ± 2.3[a]

[a]Values followed by different letter in the same row are significantly different ($p < .05$).

TABLE 4 Sensory analysis of pound cakes

Formula	70-0	70-1	90-0	90-1
Score liking*	2.60 ± 1.04[b]	3.41 ± 0.88[c]	1.72 ± 0.97[a]	2.26 ± 0.87[b]
Preference (%)**	65.0	85.3	43.0	56.5

[a]Values followed by different letter in the same row are significantly different ($p < .05$).
*Liking degree (one less liked, four more liked).
**The preference considers the consistency of crumb, softness, flavor.

TABLE 5 Fatty acid profile of pound cakes

g/100 g grasa	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3	C20:4
Control	0.76	0.79	11.07	3.92	20.78	9.11	20.18	25.41	3.0	0.27
70-1	0.20	0.22	3.21	1.25	10.91	4.81	37.19	20.61	14.62	0.42

(2007), the crumb coloration in a fat-reduced cake is more affected by the ingredients of the formula than by the Maillard reaction; also Luna et al. (2013) and Coelho & Salas-Mellado (2015) observed a reduction of the color L values evaluated in cakes added with chia flour, which resulted in a darker crumb. Otherwise, cake crumbs tended to the yellow (b^*) more than to the red (a^*), and the b^* value decreased as oil proportion increased tending to a browner coloration, which was visually more pleasing. The structure of the crumbs (Figure 4) shows that 90-0 and 90-1 cakes have larger cavities, possibly due to the coalescence of the bubbles before the formation of the pound cake structure because of the lower viscosity of the oil and the melting of the gelatin gel (Sánchez-Paz et al., 2018).

3.4 | Sensory analysis

Table 4 shows the sensory analysis of the cakes, where the most pleasing sample was 70-1 cake (acceptance of 85.3%) with a soft, a consistent crumb and more pleasing taste. Sánchez-Paz et al. (2018) studied the effect of the addition of different gelatin concentrations on a pound cake reduced in margarine. These authors concluded that gelatin gives moisture and consistency to the crumb, which makes it more pleasing to the palate when its concentration is less than 2%. In addition, 70-0 cake had an acceptance of 65%, with a softer crumb and pleasing taste, but it was more crumbly. 90-1 and 90-0 cakes were softer and had a drier crumb with an oily taste.

3.5 | Fatty acid profile analysis

The results of the sensory analysis were taken into account for the fatty acid profile evaluation; therefore, only the most pleasing samples (70-1) and control cake were evaluated. Table 5 shows these results. In the 70-1 cake, the content of C8:0 and C14:0 reduced 70% approximately, while the content of C16:0 and C18:0 reduced 47% compared to the control (100% margarine). The content of these saturated fatty acids are lower than those reported by Luna et al. (2013), who evaluated a pound cake added with chia flour. Besides, Oleic acid (C18:1) increased 46% which was slightly higher than the one reported by Luna et al. (2013). The presence of this unsaturated fatty acid is due to the addition of canola oil. The linoleic acid remains constant in both samples, but the most relevant contribution is the linolenic acid (C18:3), omega-3 content, which increases 79.5% compared to the control; this value was higher than the value reported by Luna et al. (2013), where it increased 50%. Therefore, the pound cake developed in the current work has an important content of omega-3 reducing the W6:W3 ratio to 1.4:1. The mixture of canola-chia oils was a good alternative to improve the omega-6:omega-3 ratio.

4 | CONCLUSIONS

SG increased as the mixture of canola-chia oils and gelatin content increased, while viscoelasticity of the cake batter increased only as the gelatin content increased. The addition of the mixture of canola-chia oils did not modify the temperature of the phase change during the baking process. The cakes added with oils and gelatin were softer and their color was browner compared to the control. The volume was higher and the crumb was more uniform in the cake 70-0, but sensorially, the most accepted sample was 70-1. The last cake had an important content of omega-3, with a W6 and W3 balance (1.4:1). According to these results, the mixture of chia-canola oils and gelatin addition could improve the nutritional quality of cakes reduced in margarine; therefore, studies about the effect of the addition of these ingredients on the cake quality during storage are necessary.

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